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APPLICATION FOR LETTERS PATENT

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**Methods Of Bonding Solder Balls To Bond Pads
On A Substrate, And Bonding Frames**

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1 **METHODS OF BONDING SOLDER BALLS TO BOND PADS ON A**
2 **SUBSTRATE, AND BONDING FRAMES**

3 **TECHNICAL FIELD**

4 The present invention relates to methods of bonding solder balls
5 to bond pads on a substrate, and to bonding frames.

6
7 **BACKGROUND OF THE INVENTION**

8 As integrated circuitry becomes smaller and more dense, needs
9 arise relative to the packaging and interconnecting of fabricated
10 integrated circuitry devices. Concerns associated with increasing the
11 speed with which integrated circuitry devices are packaged and the
12 efficiency with which the devices are packaged drive the industry to find
13 faster and more flexible systems and methods for packaging integrated
14 circuitry. Specifically, one aspect of integrated circuitry packaging
15 includes bonding conductive balls or solder balls on bond pads of a
16 substrate for subsequent connection to packaging structure. Such is
17 commonly referred to as solder ball bumping.

18 In the formation of solder-bumped substrates, solder ball material
19 is provided over bond pads of a substrate supporting integrated circuitry
20 thereon. If the substrates are to be flip-chip bonded to another
21 substrate, it is important that the solder balls be of uniform size.
22 Otherwise, some of the balls might not make desirable contact with the
23 bond pads of the substrate to which it is to be bonded. This problem
24 led to development of pre-formed solder balls which are formed to a

1 specific common tolerance dimension such that all of the solder balls
2 are essentially the same size. Hence, when the solder balls are bonded
3 by solder melting/welding to substrates, each will essentially project from
4 the outer substrate surface a common distance and accordingly make
5 contact with all bond pads when being bonded.

6 This invention arose out of concerns associated with providing
7 improved methods and ^{apparatus} apparatuses for packaging integrated circuitry.

8
9 SUMMARY OF THE INVENTION

10 Methods and ^{apparatus} apparatuses for bonding solder balls to bond pads
11 are described. In one embodiment, portions of a plurality of solder
12 balls are placed within a frame and in registered alignment with
13 individual bond pads over a substrate. While the ball portions are
14 within the frame, the balls are exposed to bonding conditions effective
15 to bond the balls with their associated bond pads. In another
16 embodiment, a frame is provided having a plurality of holes sized to
17 receive individual solder balls. Individual balls are delivered into the
18 holes from over the frame. The balls are placed into registered
19 alignment with a plurality of individual bond pads over a substrate while
20 the balls are in the holes. The balls are bonded with the individual
21 associated bond pads. In another embodiment, a frame is provided
22 having a hole. A solder ball is provided having an outer surface. The
23 solder ball is retained within the hole in an ambient processing
24 environment which is generally uniform over the entirety of the ball's

1 outer surface. While the solder ball is within the hole, the solder ball
2 is bonded with an associated bond pad on a substrate.

3 4 BRIEF DESCRIPTION OF THE DRAWINGS

5 Preferred embodiments of the invention are described below with
6 reference to the following accompanying drawings.

7 Fig. 1 is a side elevational view of a portion of a frame which
8 is disposed in a position to receive one or more solder balls in
9 accordance with one or more embodiments of the present invention.

10 Fig. 2 is a side elevational view of a portion of a frame which
11 is disposed in a position to receive one or more solder balls in
12 accordance with one or more embodiments of the present invention.

13 Fig. 3 is a side elevational view of a portion of a frame which
14 is disposed in a position to receive one or more solder balls in
15 accordance with one or more embodiments of the present invention.

16 Fig. 4 is a side elevational view of a frame engaged with a
17 substrate in accordance with one or more embodiments of the invention.
18 A portion of the frame has been broken away to show detail.

19 Fig. 5 is a view of the Fig. 4 frame undergoing processing in
20 accordance with one embodiment of the invention.

21 Fig. 6 is a view of the Fig. 4 frame undergoing processing in
22 accordance with one embodiment of the invention.
23
24

Fig. 7 is a view of the Fig. 4 frame and substrate after the solder balls have been bonded with their individual associated bond pads.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

Referring to Fig. 1, a portion of a frame in accordance with one embodiment of the invention is shown generally at 10 and includes an outer surface 12 having at least one, and preferably a plurality of holes 14 therein. Holes 14 are preferably sized to receive individual solder balls 16 having individual solder ball outer surfaces 18. In one embodiment, the frame and holes are dimensioned to permit one and only one solder ball to be received within each hole at a time. In a preferred embodiment, a majority portion of an associated solder ball is received within each hole.

The solder balls can be provided into frame-supported positions in a variety of ways. In one embodiment, individual solder balls 16 are delivered into holes 14 from over frame 10, as Fig. 1 implies. In another embodiment (Fig. 2) a plurality of solder balls 16 are provided over surface 12, at least some of which being deposited into at least some of holes 14. The balls can be provided over the surface in any manner. In the illustrated example, balls 16 are provided over

1 surface 12 by rolling at least one, and preferably a plurality of the
2 balls over the surface and into individual respective holes 14. The balls
3 can be rolled over the frame surface until individual balls drop into
4 individual associated holes. Alternately considered, frame 10 positioned
5 in proximity to a substrate (not shown) to which conductive balls are
6 to be bonded can be dipped into a volume of balls. Thereafter, the
7 frame and substrate are removed from the volume of balls, with
8 individual balls be received in respective frame holes. The balls are
9 preferably small enough to pass through the holes.

10 Referring to Fig. 3, and in accordance with another embodiment
11 of the invention, more solder balls 16 are provided than there are holes
12 in outer surface 12. In this example, three solder balls 16 are
13 provided for the two illustrated holes 14. One of the balls and the
14 frame is moved relative to the other of the balls and the frame
15 effective to deposit a ball into each hole. In this example, balls 16
16 are moved over surface 12 effective to deposit one solder ball into each
17 hole. Excess solder balls, such as the leftmost solder ball 16, which
18 were not deposited into a hole are removed from over surface 12.
19 Removal of excess balls can be effected in any suitable way.
20 Alternately considered, frame 10 positioned in proximity to a substrate
21 (not shown) to which conductive balls are to be bonded can be dipped
22 into a volume of balls. Thereafter, the frame and substrate are
23 removed from the volume of balls, with individual balls ^{being} received in
24 respective frame holes.

1 Referring to Fig. 4, frame 10 is shown in proximity with a
2 substrate 20 having thereon a plurality of bond pads 22. Holes 14
3 hold one individual solder ball respectively, in registered alignment with
4 an associated bond pad 22 on substrate 20. In one embodiment, each
5 solder ball 16 is placed on a fluxless bond pad surface. Fluxless bond
6 pad surfaces are preferably used in this embodiment because the frame
7 maintains each individual solder ball in registered alignment with an
8 associated bond pad prior to and during solder ball bonding described
9 below. This embodiment can overcome some problems presented
10 through the use of flux on bond pads. Specifically, flux will typically
11 have to be completely cleaned from a substrate after the bonding
12 process. This embodiment can permit the post-bonding cleaning step
13 to be eliminated thereby simplifying the bonding process.

14 This embodiment also permits at least two solder balls 16 to be
15 contemporaneously retained over different respective bond pads on
16 substrate 20. In a preferred embodiment, frame 10 is moved to
17 proximate substrate 20 before any of the balls are delivered into the
18 holes. Subsequently, individual balls can be provided or delivered into
19 the holes as described above.

20 In another embodiment, the solder balls are retained within each
21 hole in an ambient processing environment which is generally uniform
22 over the entirety of each ball's outer surface 18. Specifically, while
23 each ball is retained within its associated hole and in registered
24 alignment with an associated bond pad, the processing environment

1 outwardly of each ball is generally uniform. That is, retaining each ball
2 within its respective hole can take place without the use of any outside
3 environment-changing conditions such as vacuum pressure and the like
4 on only a portion of the respective balls. The balls are preferably
5 inserted into their associated hole from a position within the ambient
6 processing environment without separately and discretely providing a
7 vacuum force against only portions of each ball during bonding. Such
8 non-vacuum retention provides more flexibility and increases the
9 simplicity with which the balls can be processed.

10 Once having been placed in proximity with their individual
11 associated bond pads, the individual solder balls can be bonded with
12 their bond pads. The balls can be bonded separately, or can be
13 bonded all at once as through suitable heat processing. Such can take
14 place in any suitable manner, with but two examples being described
15 below in connection with Figs. 5 and 6.

16 Referring to Figs. 5 and 6, solder balls 16 are exposed to
17 bonding conditions effective to bond the balls with their associated bond
18 pads 22. In one embodiment, the solder balls are reflowed under such
19 bonding conditions while they are within their individual holes. For
20 example, the two leftmost balls in Fig. 5 and the three rightmost balls
21 in Fig. 6 are seen to have been reflowed while within their individual
22 holes. In a preferred embodiment, a laser-bonding system 24 is
23 provided and solder balls 16 are laser-bonded with their associated bond
24 pads.

1 In one laser-bonding embodiment (Fig. 5), laser bonding is
2 effected by fixing the position of frame 10 and moving a laser beam 26
3 relative to the frame from ball-to-ball. In this way, a laser beam is
4 moved relative to and between individual balls to engage each ball.

5 In another laser-bonding embodiment (Fig. 6), laser bonding is
6 effectuated by fixing the position of a laser beam 26 and moving
7 frame 10 relative to the laser beam from ball-to-ball. In this example,
8 frame 10 is moved in the direction of the arrow immediately below
9 substrate 20. Accordingly, the three rightmost solder balls 16 have been
10 reflowed by laser 26 while the four leftmost solder balls remain to be
11 processed. Such comprises moving individual solder balls relative to a
12 generally-fixed laser beam.

13 Referring to Fig. 7, frame 10 is moved away from proximity with
14 substrate 20. Preferably, frame 10 is moved away from substrate 20
15 after individual solder balls are exposed to the bonding conditions. In
16 this example, the holes are preferably dimensioned so that they do not
17 overly restrict removal of the frame after the balls are reflowed.
18 Accordingly, such comprises removing individual holes from around their
19 associated reflowed balls. Of course, the frame could be moved away
20 from the substrate prior to the exposure of the balls to the bonding
21 conditions, particularly if flux or some other agent or means is used to
22 retain the balls on their pads during bonding.

23 In another aspect of the invention, a frame is provided having a
24 plurality of ball-supporting features which maintain at least two balls in

1 registered alignment with a substrate having bond pads thereon. In a
2 preferred embodiment, the ball-supporting features comprise individual
3 holes which extend through the frame and which are dimensioned to
4 receive only one ball at a time. The holes are preferably disposed
5 over the frame in a template-like orientation which matches the
6 orientation of bond pads with which the solder balls are desired to be
7 bonded. The inventive frames can enable a large number of solder
8 balls to be simultaneously placed into bond pad-engaging positions where
9 they can be subsequently bonded in a time-saving fashion.

10 Aspects of the invention enable solder balls to be placed with
11 greater precision and in greater numbers than was previously possible.
12 Such enables throughput to be increased and provides for better
13 integrated circuitry packaging uniformity. In addition, solders balls can
14 be placed and bonded in greater numbers on fluxless bond pads which
15 can increase throughput by expediting processing.

16 In compliance with the statute, the invention has been described
17 in language more or less specific as to structural and methodical
18 features. It is to be understood, however, that the invention is not
19 limited to the specific features shown and described, since the means
20 herein disclosed comprise preferred forms of putting the invention into
21 effect. The invention is, therefore, claimed in any of its forms or
22 modifications within the proper scope of the appended claims
23 appropriately interpreted in accordance with the doctrine of equivalents.
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